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Attempts to anchor pelagic fairy prions (*Pachyptila turtur*) to their release site on Mana Island

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Abstract New Zealand conservation managers have a distinguished history in translocating forest birds, shorebirds and waterfowl to achieve conservation gains. Although New Zealand is a centre of seabird diversity, and many species are threatened and/or have suffered human-induced range reductions, until recently there had been few attempts to translocate seabirds. Reluctance to attempt translocations was due largely to the perceived risk of dispersal, and the expectation that birds would return to their source colony. Translocations have now been attempted with 10 species of burrow-nesting petrels in New Zealand, with chicks moved before they were likely to have developed awareness of their natal colony location, and hand-fed until they fledged. The translocation of 240 fairy prion chicks from Takapourewa (Stephens I) to Mana I in 2002-04 was one of few petrel translocation studies where systematic searches for returning translocated chicks at both the release site and the source colony were undertaken, and where a sample of marked control chicks allowed comparison of natural return rates with those of translocated chicks. Twenty translocated chicks returned to Mana I during 2004-12, and 25 were recovered at the source colony during 2005-08. Nearly identical proportions (*c.*20%) of translocated and control chicks were recovered, with higher recovery rates at the release site for each successive cohort. Birds appeared to develop their homing ability at different ages, and there was no apparent maximum age after which chicks should not be translocated. Exposing chicks to the source colony surface in daylight did not increase the risk of them returning to the source colony.

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INTRODUCTION

History of seabird translocations in New Zealand

New Zealand has a long history of successful translocations of birds for conservation purposes, dating back to Richard Henry's releases of South Island brown kiwi (*Apteryx australis australis*) on 3 islands in Dusky Sound in 1895-97 (Hill & Hill 1987; Miskelly & Powlesland 2013). More than a century later 49 taxa of New Zealand land birds, shorebirds and waterfowl have been translocated successfully as part of species recovery and site restoration programmes (Miskelly & Powlesland 2013).

New Zealand is the world centre of diversity for penguins, albatrosses, petrels and cormorants, and many of these species are threatened (Taylor 2000; Miskelly *et al*. 2008). Why then did no-one in New Zealand attempt to translocate a seabird species until 1986 (Imber *et al*. 2003; Miskelly *et*

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al. 2009), over 90 years after Richard Henry began his pioneering efforts with land birds? The major impediment to initiation of translocation trials with seabirds was their extreme philopatry and homing ability. Most seabirds are extremely faithful to their breeding sites, and most also recruit to the near vicinity of where they were reared (Warham 1990, 1996; Imber *et al*. 2003; Brooke 2004; Gaston 2004). Trials with breeding Manx shearwaters (*Puffinus puffinus*) released thousands of kilometres from their breeding burrows proved their extreme homing ability (Lockley 1952; Brooke 1990).

Burrow-nesting seabirds in the families Alcidae (auks), Spheniscidae (penguins) and the order Procellariiformes (petrels) were the obvious candidate seabird species for initial translocation trials, as burrows protect unattended chicks from aerial predators, and chicks cannot gain visual clues to aid homing until they emerge onto the colony surface (see Kress & Nettleship 1988; Miskelly & Taylor 2004; Priddel *et al*. 2006; Miskelly *et al*. 2009). Serventy (1967) had previously established that short-tailed shearwaters (*Puffinus tenuirostris*) reared from translocated and cross-fostered eggs returned to the site of hatching, not to where the eggs were laid, and so philopatry in petrels is presumed to develop during the nestling period.

Trials with petrel chick translocations in New Zealand began with black petrels (*Procellaria parkinsoni*) in 1986-90 (Imber *et al*. 2003), fluttering shearwaters (*Puffinus gavia*) in 1991-96 (Bell *et al*. 2005) and common diving petrels (*Pelecanoides urinatrix*) in 1997-99 (Miskelly & Taylor 2004). By 2012, 10 species of burrow-nesting petrels had been translocated in New Zealand, and at least 5 other species elsewhere in the world (Miskelly *et al*. 2009; Miskelly & Powlesland 2013). We here report on the first attempt to translocate a species of prion (genus *Pachyptila*, family Procellariidae).

Prions as ecosystem engineers

Prions are among the most abundant seabirds in the Southern Ocean. The largest colonies of 5 of the 6 species number in the millions of pairs, with burrow densities often exceeding 1 m^{-2} (Marchant & Higgins 1990; Warham 1990; Brooke 2004; Gaston 2004). The vast size and high density of prion colonies result in these small seabirds having considerable impacts on the terrestrial ecology of their breeding sites due to their burrowing activity, trampling, harvesting of living and dead plant material for nest-lining, and deposition of enormous quantities of marine-derived nutrients via faeces, spilt regurgitations, lost feathers, failed eggs and corpses (Smith 1976; Furness 1991; Bancroft *et al*. 2004, 2005; Hawke & Newman 2004; McKechnie 2006; Grant-Hoffman *et al*. 2010; Ellis *et al*. 2011; Mulder *et al*. 2011; Smith *et al*. 2011). Ecosystem effects of dense fairy prion (*Pachyptila turtur*) colonies on islands in Cook Strait, New Zealand include changes in landform, soil fertility, vegetation structure, composition and productivity, and increased densities of invertebrates and reptiles (Mulder & Keall 2001; Markwell & Daugherty 2002; Jones 2010). The ecological benefits of the establishment of dense colonies of burrow-nesting seabirds were the primary motivation for translocations of fairy prions, common diving petrels and fluttering shearwaters as part of the restoration of 217 ha Mana Island Scientific Reserve in eastern Cook Strait (Miskelly 1999; Miskelly & Taylor 2004; Miskelly *et al*. 2009; Gummer & Adams 2010).

Breeding ecology of fairy prions in Cook Strait

There is a long history of ecological research on Takapourewa (Stephens I) in western Cook Strait, mainly focussed on the large population of tuatara (*Sphenodon punctatus*) there (Brown 2001). Despite the enormous population of fairy prions on Takapourewa, and their multiple interactions with tuatara, several basic parameters of prion breeding ecology on the island were not known before this study, including the length of incubation and nestling periods, fledging weights and wing length, and the age of first breeding (but see Walls (1978) for a summary of the fairy prion breeding cycle on Takapourewa). Fairy prions have been studied at other sites in New Zealand (Richdale 1944 & 1965; Harper 1976; Miskelly *et al*. 2001); the following summary is based on those studies, plus Walls (1978), Marchant & Higgins (1990), Gaston & Scofield (1995) and Miskelly *et al*. (2009).

Fairy prions in Cook Strait weigh *c*.110-150 g. They breed as socially monogamous pairs, returning to colonies mainly from late Jun, and laying a single egg in late Oct to early Nov in a burrow 0.4-1.2 m long. Eggs hatch during Dec after 44-54 days of shared incubation. The chick is left unattended during daytime following a 2-3 day post-hatch guard period. Both adults feed the chick during nocturnal visits to the colony until the chick fledges from late Jan through to mid Feb, 43-56 days after hatching. Adults continue to feed chicks right through to fledging (there is no desertion period), and chicks spend an average of 1 night only on the colony surface before fledging (range 0-4 nights). They do not return to the colony until near breeding age (3+ years old; this study).

METHODS

Translocation of fairy prion chicks

Fairy prion chicks were translocated from Takapourewa to Mana I on 13 Jan 2002 (40 chicks), 14 Jan 2003 (100 chicks), and 17 Jan 2004 (100 chicks). Chicks were selected on the basis of weight and wing-length, to ensure that all birds moved were in good condition (> 117 g when first handled, > 93 g on the day of transfer 2-4 days later), and that a range of ages from 3-20 days before fledging was represented in the sample. Wing-length was used as a proxy age measure: the 240 translocated fairy prions fledged at wing-lengths of 168.6 ± s.e. 0.3 mm (range 154-182 mm), and wing-length grew at a mean rate of 3.3 mm d^{-1} (data from Miskelly & Williams 2002; Miskelly & Gummer 2003 & 2004).

Most of the birds translocated (194 of 240) were sourced from a 0.3 ha area of the 'dam paddock' on Takapourewa, facilitating subsequent searches for birds that might return as adults near their natal burrows. Takapourewa (150 ha) has a fairy prion breeding population estimated at 1.83 million pairs (Craig 2010), and so it was necessary to confine searches to a small portion of the colony.

In 2002 & 2003, all chicks were briefly removed from their burrows in daylight when first handled for measuring and the fitting of a uniquely-numbered leg-band, as well as being exposed to daylight when placed in translocation boxes on the day of transfer. In 2004, 49 of the chicks translocated were treated as in 2002 & 2003, while the remaining 51 chicks were kept under dark towels and in dark bags during handling, so that they did not see the source colony surface in daylight. Sixty-three of the 2004 chicks were sourced from the dam paddock; 28 of these were exposed to the light, and 35 kept in the dark.

Chicks were placed in cardboard pet boxes (2 birds per box, separated by a diagonal divider) and flown the 80 km between islands by helicopter (further details in Miskelly *et al*. 2009).

Care of translocated fairy prion chicks at the release site

On arrival on Mana I, chicks were given up to 5 ml of fresh water and individually placed in artificial burrows previously used for diving petrels (Miskelly & Taylor 2004). They were hand-fed daily from the day after arrival until they fledged. Three different artificial diets were used (Miskelly *et al*. 2009): 20 chicks were fed a krill-based diet in 2002, 16 chicks were fed a diet based on Ocean Catch™ tinned sardines in 2003, and the remaining 204 chicks were fed a diet based on Brunswick™ tinned sardines in soy oil. All meals were delivered as a blended slurry via a syringe and crop needle, with meal sizes averaging 26.6 g (Brunswick™ sardines, n = 1914 meals), 28.4 g (krill, n = 127) and 33.4 g (Ocean Catch™ sardines, n = 160). Details of artificial diets, feeding methodology and husbandry practices were given by Miskelly & Williams (2002), Miskelly & Gummer (2003 & 2004) and Miskelly *et al*. (2009).

Chicks were weighed daily before they were fed, and their wing lengths were also measured daily as they approached fledging. They fledged during the hours of darkness, and so fledging weights and wing measurements were taken approximately 8-16 hours before the birds departed the release site. Stick fences were placed at burrow entrances in 2003 & 2004 to allow detection of whether chicks exited their burrow for one or more nights before fledging.

Control chicks

Thirty parent-reared fairy prion chicks were weighed daily for the last 2-11 days of the nestling period on Takapourewa in Jan 2004, providing a sample of natural fledging weights. Some of these chicks were part of a larger sample of 149 control chicks of similar size to the translocated chicks that were banded and left to fledge naturally within the dam paddock chick collection and search area (42 in 2002, 20 in 2003, 87 in 2004).

Acoustic attraction at the release site

A solar-powered loud-speaker system has broadcast calls of fairy prions and other petrel species during the hours of darkness at the release site almost continuously since 1993 (Miskelly & Taylor 2004; Miskelly *et al*. 2009).

Surveys for birds that survived to adulthood

Fairy prions do not return to breeding colonies until at least 2.5 years after they fledge (data presented here). Both the 0.3 ha portion of the Takapourewa colony where the majority of chicks were sourced from and the Mana I release site were searched regularly between Aug 2004 and Dec 2008, 2.5-7 years after the first chicks were translocated. Searches continued at lower frequency on Mana I during 2009-12 (Table 1). Searches started about an hour after dark and continued for 30-180 minutes, depending on the number of birds present on the colony surface (typical duration 90 mins). Prions located on the surface of the search areas were captured where possible to check for the presence of uniquely-numbered leg bands that had been applied to study chicks. Few prions were present on Mana I, and so we attempted to catch all birds seen. Up to 550 prions were handled per night on Takapourewa, with a total of 9313 birds checked for leg bands during the 43 survey nights there. Breeding by translocated and control chicks on Takapourewa was not monitored.

From Nov 2007, feather samples from returned birds were collected for sexing using DNA techniques.

Measurements

Unless stated otherwise, measurements are presented as mean ± standard error (minimum - maximum, n = sample size).

Table 1. Search effort for returned translocated chicks at the source colony and release site. Capture rates for control chicks on Takapourewa are not shown, but they comprised part of the total number of birds handled there.

	Source colony (Takapourewa)				Release site (Mana I)			
	No. of nights of searching	Birds handled[1]	No. of recaptures[1]	No. of new recaptures	No. of nights of searching	Birds handled[1]	No. of recaptures[1]	No. of new recaptures
Jul-Dec 2004	8	877	0	0	16	6	2	1
May-Nov 2005	5	1012	2	2	5	6	2	1
Jun-Nov 2006	10	2564	26	15	10	5	3	1
Aug-Nov 2007	10	3122	22	6	2	14	12	8
Aug-Dec 2008	10	1738	6	2	6	21	19	8
Jul-Nov 2009	-	-	-	-	4	7	7	0
Nov 2010	-	-	-	-	1	2	1	0
Sep & Nov 2011	-	-	-	-	2	2	1	0
Jul & Oct 2012	-	-	-	-	2	4	3	1
Total	43	9313	56	25	48	67	50	20

[1]May include the same individuals handled on multiple nights or (due to the number of unbanded birds handled on Takapourewa) on the same night.

Table 2. Fledging weights (g) of fairy prion chicks fed on 4 different diets at Cook Strait sites during 2002-04. Note that artificial diets were used (on Mana I) for only the last 2-21 days before chicks fledged, with all birds being fed by their parents on Takapourewa for *c.*3-6 weeks before then. Natural fledging weights were obtained on Takapourewa.

Diet	Year	n	Mean ± s.e.	Minimum	Maximum
Natural (parent-reared)	2004	30	106 ± 2.1	86	132
Krill-based	2002	18[1]	104 ± 2.4	88	126
Ocean Catch™ sardines	2003	16	105 ± 1.5	94	118
Brunswick™ sardines	2002	20	115 ± 1.5	105	135
Brunswick™ sardines	2003	84	123 ± 1.2	100	149
Brunswick™ sardines	2004	100	115 ± 0.9	96	139

[1]Two chicks fed a sardine-based diet for the last 3 days they were on Mana I excluded from data.

RESULTS

Survival rate and condition of fairy prion chicks after translocation

All 240 chicks fledged in good condition 2-21 days after translocation (median 10 days). The effects of 3 different artificial diets on fledging weights were reported by Miskelly *et al*. (2009). In summary, birds fed on a krill-based diet or on a diet based on Ocean Catch™ sardines fledged at weights close to those of parent-fed chicks, while those fed on a diet based on Brunswick™ sardines fledged at significantly higher body-weights (Table 2). The very high fledging weights reached by chicks fed on Brunswick™ sardines in 2003 were due partly to the chicks being in very good condition before transfer. Body-weights for these 84 chicks on the day of transfer were 152 ± 1.8 g (111-184 g); comparative transfer weights for chicks fed on Brunswick™ sardines in 2002 were 134 ± 2.1 g (118-154 g, $n = 20$), and in 2004 were 131.2 ± 1.7 g (93-165 g, $n = 100$).

Recoveries of translocated fairy prions and control chicks as adults

Forty-five (18.8%) of the 240 translocated birds were recovered as adults, 20 on Mana I and 25 within the dam paddock on Takapourewa (*i.e.*, within metres of their natal burrows). Twenty-nine of the 149 control (non-translocated) chicks (19.5%) were also recovered in the dam paddock. No new recoveries of translocated or control birds were made during the last 7 nights of searching on Takapourewa (Nov-Dec 2008), during which 1151 birds were handled (*cf.* Table 1).

Ages of the 74 birds when first recaptured as adults were 3 years (24 birds), 4 years (31 birds), 5 years (13 birds), 6 years (5 birds), and 9 years (1 bird). Most birds were recovered as adults between Aug and Dec; as they hatched from eggs in Dec, ages were rounded up as if the birds were recovered in Dec of the year they were caught. The youngest bird recovered was 2.5 years old (a 2003

Table 3. Recovery rates of translocated fairy prion chicks fed different artificial diets, plus combined annual cohort recovery rates at both the source colony (Takapourewa) and the release site (Mana I). Data from birds sourced beyond the dam paddock search area excluded.

Artificial diet used and/or year of translocation	No. of chicks translocated	No. recovered as adults at the source colony	No. recovered as adults at the release site	Total
Krill 2002	17	0	1	1
Ocean Catch™ sardines 2003	16	1	2	3
Brunswick™ sardines 2002	14	1	0	1
Brunswick™ sardines 2003	84	13	3	16
Brunswick™ sardines 2004	63	7	11	18
Brunswick™ sardines total	161	21	14	35
2002 total	31	1	1	2
2003 total	100	14	5	19
2004 total	63	7	11	18
Combined total	194	22	17	39

transferee recaptured on Takapourewa on 9 May 2005).

Because 46 of the translocated chicks came from parts of Takapourewa that were not searched subsequently, these birds (which included 3 that returned to Mana I) were excluded from analyses of recovery rates. Of the 194 chicks translocated from the search area in the dam paddock, 39 (20.1%) were recovered on either island. There was no significant difference in recovery rates of parent-reared versus translocated chicks (χ^2 = 0.045, 1 d.f., *n.s.*).

There were marked differences in recovery rates of chicks between years (Table 3), with 2 only of the 2002 cohort recovered (6%), compared to 19 & 29% respectively for the 2003 & 2004 cohorts. The proportion of birds recovered at the release site differed greatly between the 2003 & 2004 cohorts, with 26% of the recovered birds from the 2003 cohort found on Mana I (5 out of 19) compared to 61% of the returned birds in the 2004 cohort (11 out of 18).

Sex was determined for 24 of the 45 recovered birds. The 17 sexed birds on Mana I comprised 9 males and 8 females; the 7 sexed birds on Takapourewa comprised 5 males and 2 females. The combined total of 14 males and 10 females did not differ significantly from an equal sex ratio (χ^2 = 0.414, 1 df, p = 0.52). Few studies have reported the sex ratio of petrels recovered after translocation, however 13 of 14 sexed Gould's petrels (*Pterodroma leucoptera*) that returned to their release site were male (N. Carlile, *pers. comm*. 27 Jan 2012), as were 9 of 17 sexed common diving petrels that returned to Mana I (CMM, *unpubl.*).

Relationship between fledge weight and recovery rate

There was no apparent relationship between fledge weight and the subsequent recovery of chicks as adults, nor on where the birds recruited to (Fig. 1). The mean fledging weight of 45 translocated chicks recovered as adults was 118.4 ± 1.6 g (97 - 141 g), compared to 118.2 ± 1.0 g (88 - 151 g) for 155 translocated chicks not recovered as adults (t = 0.102, P = 0.92). The mean fledging weight of the 20 translocated chicks recovered as adults on Mana I was 117.0 ± 2.2 g (102 - 134 g), compared to 119.6 ± 2.3 g (97 - 141 g) for the 25 translocated chicks recovered as adults on Takapourewa (t = 0.841, P = 0.41).

Relationship between the length of time birds were at the release site before fledging and recovery rates at the source site and release site

The length of time that translocated fairy prion chicks spent in artificial burrows on Mana I had no apparent affect on which island they were recovered on as adults (Fig. 2). One chick that was on Mana I for 18 days still returned to Takapourewa, whereas a chick that was on Mana I for 3 days only before fledging was recovered on Mana I as an adult. The median length of stay on Mana I for chicks that returned there was 10 days (n = 20, range 3 - 19 days), compared to 9 days (n = 25, range 5 - 18 days) for chicks that returned to the source colony. The median length of stay on Mana I for chicks sourced from the dam paddock that were not recovered was 11 days (n = 155, range 2 - 21 days).

The length of time that translocated chicks spent on the surface of the release site at night

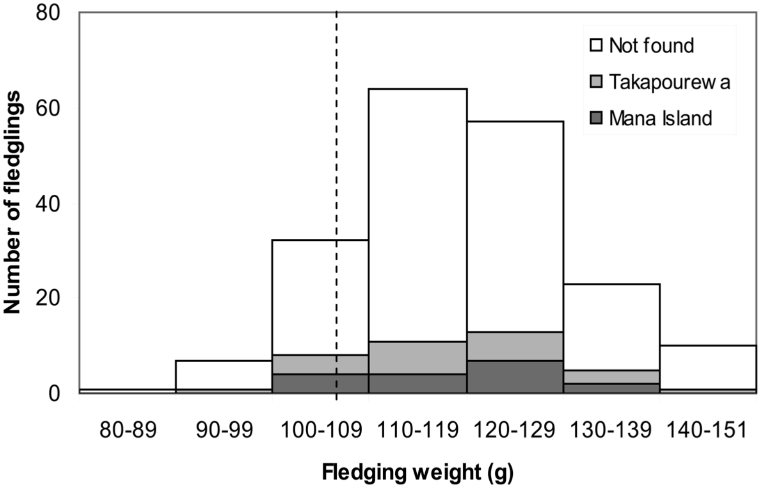

Fig. 1. Relationship between fledging weight and subsequent recovery of translocated fairy prions as adults at the source colony (Takapourewa) and the release site (Mana I). Data for 46 birds sourced from beyond the dam paddock search area excluded. 'Not found' refers to the 80% of fledglings not recovered as adults. The vertical dashed line represents the mean fledging weight of parent-reared chicks.

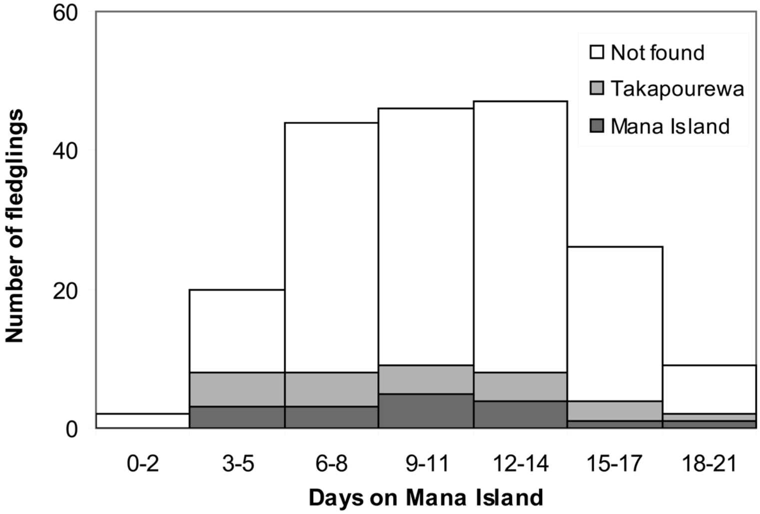

Fig. 2. Relationship between the length of time that translocated fairy prions were at the release site on Mana I before they fledged and their subsequent recovery as adults at the source colony (Takapourewa) and the release site. Data for 46 birds sourced from beyond the dam paddock search area excluded. 'Not found' refers to the 80% of fledglings not recovered as adults.

(*i.e.*, whether they fledged on the first night of emergence, or after 1+ nights on the surface; Table 4) had no significant effect on whether birds were recovered at the release site (Fisher Exact Test, P = 0.45) or at the source colony (P = 0.82).

Effect of chicks being exposed to the source colony surface in daylight on their subsequent recovery rate at the source colony

Exposing fairy prion chicks to the surface of their natal colony in daylight before translocation did not increase the likelihood that they returned to their natal colony as adults. Eighteen of the 63 chicks translocated from the dam paddock in 2004 were recovered as adults, 11 on Mana I and 7 on Takapourewa. A higher proportion of the birds exposed to their natal colony in daylight were subsequently recovered as adults at the release site compared to the natal colony (Table 5).

Recovery rates of translocated petrels of 7 species compared to control chicks

This was one of few petrel translocation studies where comprehensive searches for translocated chicks were undertaken at both the release site and the source colony. Six previous studies reported recovery (recapture) rates of translocated petrel chicks at their release site (Table 6). Three only of these studies (of black petrel *Procellaria parkinsoni*, Gould's petrel, and Bermuda petrel *Pterodroma cahow*) included comprehensive searches for translocated chicks returning to the source colony (Imber *et al*. 2003; Priddel *et al*. 2006; Carlile *et al*. 2012). However, Imber *et al*. (2003) were unable to search the release site (Hauturu) thoroughly due to its rugged topography and the scattered distribution of burrows there.

The Bermuda petrel study had the highest recovery rate of translocated chicks (24.2%; Carlile *et al*. 2012), followed by fairy prions (19.6%).

Table 4. The number of nights that translocated fairy prion chicks spent on the surface of the release site (outside their burrows, or at the burrow entrance) before fledging in relation to whether they were recovered at the source colony or at the release site. Percentages for each column are given in parentheses.

No. of nights on the colony surface	No. recovered as adults at the source colony	No. recovered as adults at the release site	Not recovered	Total
0	16 (69.6)	11 (57.9)	99 (64.7)	126 (64.6)
1	6 (26.1)	7 (36.8)	37 (24.2)	50 (25.6)
2	1 (4.3)	0	11 (7.2)	12 (6.2)
3	0	0	5 (3.3)	5 (2.6)
4	0	1 (5.3)	1 (0.7)	2 (1.0)
Total	23	19	153	195

Table 5. Effect of exposure to the natal colony surface in daylight on subsequent recovery of fairy prion chicks as adults at the source colony (Takapourewa) and at the release site (Mana I). All data based on chicks translocated in Jan 2004 (data from birds sourced beyond the dam paddock search area excluded).

	No. of chicks translocated	No. recovered as adults at the source colony	No. recovered as adults at the release site	Total
Chicks exposed to light	28	2	5	7
Chicks kept in the dark	35	5	6	11
Total	63	7	11	18

However, only 8.2% of fairy prions were recovered at their release site, compared to 17.2% for Bermuda petrel, 16.9% for common diving petrel, and 11.7% for fluttering shearwater (Miskelly & Taylor 2004; Bell *et al*. 2005; Carlile *et al*. 2012).

Three previous studies included data on recovery rates of non-translocated chicks at natal colonies, with recovery rates of up to 58.6% per cohort for Bermuda petrel (Carlile *et al*. 2012), 41.4% for short-tailed shearwater *Puffinus tenuirostris* (see Serventy & Curry 1984), and 6.5% for black petrel (Imber *et al*. 2003), compared to 19.5% for fairy prion.

Role of resident birds as anchors for subsequent cohorts

Nearly all petrel translocation studies where more than 10 chicks returned had low recovery rates of the first cohort translocated, with higher (and typically increasing) recovery rates of second and subsequent cohorts (Table 7). The one exception was Gould's petrels on Boondelbah I, where almost identical proportions of both cohorts were recovered at the release site. Boondelbah I was the only site among the 5 release sites where conspecifics were already present and breeding (Priddel *et al*. 2006).

The pattern of increased recruitment of the second and subsequent cohorts of petrels translocated to new sites is probably due to the presence of increasing numbers of adult conspecifics at the release site attracting more returning birds to land and to remain long enough at the site to be detected during occasional surveys. This implies that a proportion of the birds from early cohorts that returned to the release sites were not detected, and presumably recruited elsewhere. An estimate of the number of fairy prions from early cohorts that failed to recruit at the release site can be obtained from comparison with return rates to the source colony, where the level of social attraction was constant between seasons.

The proportion of translocated birds detected in the dam paddock on Takapourewa varied from 3.2 to 14.0% each year (Table 8), and was strongly correlated with recovery rates of control chicks from the same cohort (Table 8; $r = 0.962$). Based on the ratio of translocated chicks recovered at each site from the 2004 cohort (Mana I = 1.58 x Takapourewa) when those birds returning to Mana I would have encountered other adult fairy prions at the release site, we estimate that *c*.17% of the 2003 cohort probably returned to Mana I but did not recruit there, and were not detected in either search area (Table 9). Similarly, assuming equal sex ratios and survival among translocated chicks, we estimate that *c*.9 females recruited outside the search areas (Table 9).

Breeding by fairy prions on Mana I

Twenty-five adult fairy prions were handled on Mana I during 2004-2012: 20 translocated birds that returned as adults, 4 unbanded birds, and

Table 6. Recovery rates of translocated chicks of 7 species of burrow-nesting petrels at release sites and source colonies, plus recovery rates of control (non-translocated) chicks for 4 of the species. Most studies had limited survey effort at either release or source site, and these minimum data are shown in parentheses. 'Translocated' totals refer to the number of chicks believed to have fledged (see original references for pre-fledging mortality). Fairy prion data exclude 46 chicks sourced from beyond the dam paddock search area. Scientific names for all species are given in the text.

Species	Sample	Sample size	Recovered at release site		Recovered at source colony		Total recovered		Reference
			n	%	n	%	N	%	
Short-tailed shearwater	Translocated	157	5	3.2	-	-	(5)	(3.2)	Serventy *et al*. 1989
	Control	922	-	-	382	41.4	382	41.4	Serventy & Curry 1984
Black petrel	Translocated	249	(2)	(0.8)	16	6.4	(18)	(7.2)	Imber *et al*. 2003
	Control	279	-	-	18	6.5	18	6.5	
Common diving petrel	Translocated	118	20	16.9	-	-	(20)	(16.9)	Miskelly & Taylor 2004
Fluttering shearwater	Translocated	273	32	11.7	(1)	(0.4)	(33)	(12.1)	Bell *et al*. 2005
Gould's petrel	Translocated	195	15	7.7	3	1.5	18	9.2	N. Carlile, *pers. comm*.
Bermuda petrel (2004-08 cohorts)[1]	Translocated	99	17	17.2	7	7.7	24	24.2	Carlile *et al*. 2012
	Control	29	1	3.4	7	24.1	8	27.6	
Fairy prion	Translocated	194	17	8.8	22	11.3	39	20.1	This study
	Control	149	-	-	29	19.5	29	19.5	

[1]Further translocated and control chicks are expected to return

Table 7. Cohort recovery rates (percent of translocated chicks) at release sites for 5 species of translocated petrels. Apart from Gould's petrel (where a breeding colony of conspecifics was already present on the release island), all species had lower recovery rates of the first cohort compared to subsequent cohorts. Data for Bermuda petrels was presented too soon for all chicks from later cohorts (at least) to have returned, and these partial recruitment estimates are shown in parentheses.

	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Cohort 5	Reference
Diving petrel	11.5	22.5	19.2			Miskelly & Taylor (2004)
Fluttering shearwater	4.2	11.9	10.3	21.6	32.0	Bell *et al*. (2005)
Gould's petrel	5.3	5.0				Priddel *et al*. (2006)
Bermuda petrel	28.6	57.1	(30)	(8)		Carlile *et al*. (2012)
Fairy prion	2.5	5.0	17.5			This study

one locally-reared chick (first recovered when nearly 5 years old). An unbanded pair reared a chick in 2005/06, but one of the adults was not seen subsequently. At least 6 other pairs of prions bred on the island between 2007/08 and 2011/12, with 9 chicks reared to fledging in known, accessible burrows during these 5 breeding seasons. Identities of all the breeding birds each year were not known, but they included at least 7 translocated birds (and possibly all but one of the remaining breeding adults had been translocated). Several pairs bred in long natural burrows where the nesting chambers were inaccessible, and it is estimated that up to 8 additional chicks were reared during these 5 breeding seasons (based on evidence of burrow visits late in the nestling period). In 2011/12, 5-6 pairs of prions were believed to be occupying burrows at the release site, and 4 chicks fledged.

The minimum age of first breeding by translocated fairy prion males and females on Mana I was 3 years 10 months after hatching.

DISCUSSION

This first translocation of a species of prion achieved an unprecedented 100% fledging success for a petrel chick translocation, with all 240 birds fledging in good condition. Heaviest fledging weights were achieved by the 204 chicks fed a diet based on Brunswick™ sardines in soy oil blended with fresh water, delivered daily into the proventriculus via a syringe fitted with a crop needle. This is an easy, practical diet and method to use for petrel translocations at remote field sites (Miskelly *et al*. 2009).

The recovery rate of translocated fairy prion chicks as adults (20.1%) was the second highest recorded for a translocated petrel species (after Bermuda petrel, see Carlile *et al*. 2012), although higher recovery totals might have been reached by translocated common diving petrels (minimum 16.9%) and fluttering shearwaters (minimum 12.1%) if the source colonies had been adequately searched for returning chicks (data from Miskelly & Taylor 2004; Bell *et al*. 2005). The similarity between the recovery rates of translocated prions (20.1%) and control (non-translocated) chicks (19.5%) was surprising given several factors expected to reduce recovery rates of translocated chicks. Firstly, the process of translocating chicks 80 km, handling them daily for up to 3 weeks, and feeding them an unfamiliar diet, would all be expected to impact on post-fledging survival rates. Secondly, we expected that translocated chicks would be at greater risk than control chicks of recruiting to fairy prion colonies located between the release site and source colony, including the Brothers Is (28 km from Mana I, 62 km from Takapourewa) and the Trio Is (71 km from Mana I, 19 km from Takapourewa). It is also unlikely that none of the translocated birds recruited among the estimated 1.83 million pairs of prions (Craig 2010) in the 99.8% of Takapourewa that was not searched for returning chicks. The most likely explanation for the similar recovery rates of translocated and control chicks is that the high fledging weights achieved using the sardine diet increased the survival to adulthood of translocated prions compared to control chicks, and that coincidentally this increased survival exactly offset any 'leakage' of translocated birds recruiting to sites other than the release site and the immediate vicinity of natal burrows.

Unlike several previous petrel translocation studies (Imber *et al*. 2003; Miskelly & Taylor 2004; Bell *et al*. 2005), we found no tendency for higher recovery rates of heavier fledglings. A likely explanation for this is that most of the translocated chicks fledged with above-average weight: 207 (86%) of fledglings exceeded the mean fledging weight of parent-reared chicks on Takapourewa (105.9 g). Similarly, there was no relationship between fledging weight and whether chicks recruited to the release site or source colony.

The large number of chicks that returned to Takapourewa, and the absence of any relationship between the time that chicks spent at the release site and where they were recovered as adults were both unexpected. Fairy prion chicks do not emerge from their burrows until the night of fledging or the night before (exceptionally up to 4 nights before) (Richdale 1965; Harper 1976; Table 4). It is therefore unlikely that any of the translocated chicks had ventured onto the source colony surface before translocation. Although burrows were short, almost all were curved, and it is unlikely that more than a handful of chicks could have viewed the burrow entrance from the nest chamber. However, we had no way to determine whether chicks had moved up towards the burrow entrance at night sufficiently to see some of their surroundings, even if they did not fully emerge from the burrow. Alternatively, the birds could be using non-visual cues to allow recognition of the vicinity of their natal burrows as adults. Odour is known to be a close-range cue for prions locating their burrows (Bonadonna & Bretagnolle 2002; Bonadonna *et al*. 2003), but is unlikely to aid birds choosing between 2 potential recruitment sites situated 80 km apart. Regardless of the mechanism used, the recovery of so many 'pre-emerged' chicks within metres of their natal burrows demonstrates that this philopatric ability can develop more than 2 weeks before fledging in prions, and that it is extraordinarily accurate even when chicks have had little or no opportunity to see the night sky or view the silhouette of the landscape surrounding their burrow.

Table 8. Recovery rates (%) of fairy prion control chicks and translocated chicks at the source site and release site, separated by cohort.

	Cohort			Total
	2002	2003	2004	
Control chicks recovered at source site	4.8	25.0	25.3	19.5
Translocated chicks recovered at source site	3.2	14.0	11.1	11.3
Translocated chicks recovered at release site	3.2	5.0	17.5	8.8

Our discovery that allowing chicks to see their natal colony surface in daylight did not increase the likelihood of them returning to the colony greatly simplifies the selection and collection of petrel chicks for transfer, when it is typically necessary to extract hundreds of chicks from burrows 2 or more times before they are translocated. This variable has not been mentioned in previous petrel translocation studies, and we assume that chicks in all other studies had the opportunity to see their natal colony surface during either day or night during handling. Chicks may be more sensitive to visual cues at night, as both adults and fledglings avoid the colony surface in daylight. We recommend that care be taken if petrel chicks are extracted from burrows at night before translocation, unless this is part of the experimental design.

Several studies have revealed that male

Table 9. Observed and estimated fates for all 240 fairy prion chicks translocated to Mana I based on recovery rates of birds sourced from the dam paddock search area on Takapourewa. Missing females were estimated assuming equal sex ratios and survival within each cohort. Birds that failed to recruit on Mana in 2003 were estimated assuming the same percentage total of the cohort recruited to the source site in each year as for the 2004 cohort (42% of survivors). This was the only cohort for which we believe that there were sufficient adult prions at both sites to aid recruitment.

	Cohort			Total
	2002	2003	2004	
Recovered at release site	1	5	14	20
Recovered at source site	1	14	10	25
Sourced from outside the search area, and estimated to have recruited elsewhere on Takapourewa	0	0	4	4
Estimated to have recruited away from Mana I due to low social attraction there	0	15	0	15
Females estimated to have recruited beyond search areas	0	6	3	9
Not accounted for (presumed dead)	38	60	69	167
Total	40	100	100	240

procellariiforms are more likely to recruit close to natal burrows than females, with females more likely to disperse to other colonies or other parts of the same colony (Fisher 1976; Brooke 1978, 1990; Rabouam *et al*. 1998). Our results indicated a similar trend (58% of recovered birds were male), but this sex ratio was not significantly different from 1:1. Assuming that sex ratios were equal in the sample of chicks fledged, and that similar proportions survived to adulthood, it is possible that up to 24% of fledglings survived (*cf.* 20.1% recorded), with *c.*36% of females recruiting outside the 2 search areas.

Recognition that petrels translocated to new sites have low recruitment rates until some adults have recruited to the site has important consequences for future translocations. We suggest that the presence of adult birds greatly increases the perceived suitability of release sites to pre-breeders compared to aural stimuli alone. This realisation lends support to multi-year translocations (*cf.* single releases), with increasing sample sizes for later cohorts when there is a higher likelihood of returning chicks encountering adult conspecifics at the release site. Further, supplementary translocations (e.g. to sites with remnant populations, or where translocations have had limited success) are likely to result in higher recruitment than translocations to sites where the target species is absent.

We recorded a high survival rate of translocated birds to adulthood, but only 8% (20 birds) were recovered as adults at the release site, along with 4 unbanded colonists. Ten years after the first translocation, there were fewer than 6 pairs of fairy prions known to be present on Mana I. The low level of recruitment of non-translocated birds at the release site contrasts with common diving petrel (80 non-translocated birds recorded within 11 years of the first chick translocation; Miskelly & Taylor 2004; Miskelly *et al*. 2009) and Gould's petrel (31 birds recorded within 5 years; Priddel *et al*. 2006), and has greatly impacted the establishment of a viable colony of fairy prions on Mana I. Variability in colonisation rates is apparently a species-specific trait, as both fairy prions and common diving petrels have their nearest breeding colony on the Brothers Is, 28 km from Mana I, and the calls of both species have been broadcast from loud speakers at their release site on Mana I since 1993. The fairy prion population on Mana I remains extremely vulnerable to stochastic events, and is unlikely to persist without further chick translocations.

Recommendations

This first attempt to establish a colony of fairy prions by chick translocations yielded several key pieces of information that could aid future attempts. The diet based on blended Brunswick™ sardines in soy oil and freshwater was practical and effective in ensuring hand-fed birds fledged in good condition (see also Miskelly *et al*. 2009). As only 8% of translocated chicks were recovered at the release site, we recommend that 200 additional chicks be translocated to Mana I to ensure that the colony there continues to grow. With the enhanced social attraction provided by the small fairy prion colony now on Mana I, at least 14% of the additional birds are predicted to recruit there.

To minimise hand-feeding costs and effort (and recognising that there was no age threshold at which chicks became fixed to their natal colony), chicks selected for translocation should exceed 115 g and have wing lengths of 142-162 mm (*i.e.*, targeting birds 2-8 days before fledging). It is not necessary to prevent chicks from seeing the surface of the source colony in daylight.

We also recommend that petrel translocations to new sites be undertaken over at least 3 years, with the greatest numbers of chicks translocated in the final cohort. These birds are more likely to encounter conspecifics at the release site when they return as pre-breeders, and are predicted to have higher recruitment rates than birds translocated in earlier cohorts.

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LITERATURE CITED

Bancroft, W.J.; Garkaklis, M.J.; Roberts, D.J. 2005. Burrow building in seabird colonies: a soil-forming process in island ecosystems. *Pedobiologia 49*: 149-165.

Bancroft, W.J.; Roberts, D.J.; Garkaklis, M.J. 2004. Burrowing seabirds drive decreased diversity and structural complexity, and increased productivity in insular-vegetation communities. *Australian Journal of Botany 53*: 231-241.

Bell, M.; Bell, B.D.; Bell, E.A. 2005. Translocation of fluttering shearwater (*Puffinus gavia*) chicks to create a new colony. *Notornis 52*: 11-15.

Bonadonna, F.; Bretagnolle, V. 2002. Smelling home: a good solution for burrow finding in nocturnal petrels? *Journal of Experimental Biology 205*: 2519-2523.

Bonadonna, F.; Hesters, F.; Jouventin, P. 2003. Scent of a nest: discrimination of own-nest odours in Antarctic prions (*Pachyptila desolata*). *Behavioral Ecology & Sociobiology 54*: 167-173.

Brooke, M. 1990. *The Manx shearwater*. London, T & A D Poyser.

Brooke, M. 2004. *Albatrosses and petrels across the world*. Oxford, Oxford University Press.

Brooke, M. de L. 1978. The dispersal of female Manx shearwaters. *Ibis 120*: 545-551.

Brown, D. 2001. *Stephens Island: ark of the light*. The author, Blenheim.

Carlile, N.; Priddel, D.; Madeiros, J. 2012. Establishment of a new, secure colony of endangered Bermuda petrel *Pterodroma cahow* by translocation of near-fledged nestlings. *Bird Conservation International 22*: 46-58.

Craig, E.D. 2010. Takapourewa titiwainui (fairy prion; *Pachyptila turtur*): how nest site selection affects breeding success, with applications for translocation. MSc thesis, University of Otago.

Ellis, J.C.; Bellingham, P.J.; Cameron, E.K.; Croll, D.A.; Kolb, G.S.; Kueffer, C.; Mittelhauser, G.H.; Schmidt, S.; Vidal, E.; Wait, D.A. 2011. Effects of seabirds on plant communities. Pp 177-211 in Mulder, P.H.; Anderson, W.B.; Towns, D.R.; Bellingham, P.J. (eds) *Seabird islands: ecology, invasion and restoration*. New York, Oxford University Press.

Fisher, H.I. 1976. Some dynamics of a breeding colony of Laysan albatrosses. *Wilson Bulletin 88*: 121-142.

Furness, R.W. 1991. The occurrence of burrow-nesting among birds and its influence on soil fertility and stability. Pp 53-67 *in* Meadows, P.S. & Meadows, A. (eds.) *The environmental impact of burrowing animals and animal burrows*. Symposia of the Zoological Society of London, vol. 63. Oxford, Clarendon Press.

Gaston, A.J. 2004. *Seabirds: a natural history*. New Haven, Yale University Press.

Gaston, A.J.; Scofield, R.P. 1995. Birds and tuatara on North Brother Island, Cook Strait, New Zealand. *Notornis 42*: 27-41.

Grant-Hoffman, M.N.; Mulder, C.P.H.; Bellingham, P. 2010. Invasive rat and burrowing seabird effects on seeds and seedlings on New Zealand islands. *Oecologia 163*: 449-460.

Gummer, H.; Adams, L. 2010. *Translocation techniques for fluttering shearwaters (*Puffinus gavia*): establishing a colony on Mana Island, New Zealand*. Wellington, Department of Conservation.

Harper, P.C. 1976. Breeding biology of the fairy prion (*Pachyptila turtur*) at the Poor Knights Islands, New Zealand. *New Zealand Journal of Zoology 3*: 351-371.

Hawke, D.J.; Newman, J. 2004. Inventories and elemental accumulation in peat soils of forested seabird breeding islands, southern New Zealand. *Australian Journal of Soil Research 42*: 45-48.

Hill, S.; Hill, J. 1987. *Richard Henry of Resolution Island*. Dunedin, John McIndoe.

Imber, M.J.; McFadden, I.; Bell, E.A.; Scofield, R.P. 2003. Post-fledging migration, age of first return and recruitment, and results of inter-colony translocation of black petrels (*Procellaria parkinsoni*). *Notornis 50*: 183-190.

Jones, H.P. 2010. Prognosis for ecosystem recovery following rodent eradication and seabird restoration in an island archipelago. *Ecological Applications 20*: 1204-1216.

Kress, S.W.; Nettleship, D.N. 1988. Re-establishment of Atlantic puffins (*Fratercula arctica*) at a former breeding site in the Gulf of Maine. *Journal of Field Ornithology 59*: 161-170.

Lockley, R.M. 1952. Bird navigation – swift crossing of Atlantic by a shearwater. *The Times*, 28 June 1952, p.7.

Marchant, S.; Higgins, P.J. (eds.), 1990. *Handbook of Australian, New Zealand and Antarctic Birds*. Ratites to Ducks, vol. 1. Melbourne, Oxford University Press.

Markwell, T.J.; Daugherty, C.H. 2002. Invertebrate and lizard abundance is greater on seabird-inhabited islands than on seabird-free islands in the Marlborough Sounds, New Zealand. *Ecoscience 9*: 293-299.

McKechnie, S. 2006. Biopedturbation by an island ecosystem engineer: burrowing volumes and litter deposition by sooty shearwaters (*Puffinus griseus*). *New Zealand Journal of Zoology 33*: 259-265.

Miskelly, C. 1999. *Mana Island ecological restoration plan*. Wellington, Department of Conservation.

Miskelly, C.M.; Dowding, J.E.; Elliott, G.P.; Hitchmough, R.A.; Powlesland, R.P.; Robertson, H.A.; Sagar, P.M.; Scofield, R.P.; Taylor, G.A. 2008. Conservation status of New Zealand birds, 2008. *Notornis 55*: 117-135.

Miskelly, C.; Gummer, H., 2003. *Second transfer of fairy prion (titiwainui) chicks from Takapourewa to Mana Island, January 2003*. Wellington, Department of Conservation.

Miskelly, C.; Gummer, H., 2004. *Third and final transfer of fairy prion (titiwainui) chicks from Takapourewa to Mana Island, January 2004*. Wellington, Department of Conservation.

Miskelly, C.M.; Powlesland, R.P. 2013. Conservation translocations of New Zealand birds, 1863-2012. *Notornis 60:* 3-28.

Miskelly, C.M.; Sagar, P.M.; Tennyson, A.J.D.; Scofield, R.P. 2001. Birds of the Snares Islands, New Zealand. *Notornis 48*: 1-40.

Miskelly, C.M.; Taylor, G.A. 2004. Establishment of a colony of common diving petrels (*Pelecanoides urinatrix*) by chick transfers and acoustic attraction. *Emu 104*: 205-211.

Miskelly, C.M.; Taylor, G.A.; Gummer, H.; Williams, R. 2009. Translocations of eight species of burrow-nesting seabirds (genera *Pterodroma*, *Pelecanoides*, *Pachyptila* and *Puffinus*: family Procellariidae). *Biological Conservation 142*: 1965-1980.

Miskelly, C.; Williams, R. 2002. *Transfer of fairy prion (titiwainui) chicks from Takapourewa to Mana Island, January 2002*. Wellington, Department of Conservation.

Mulder, C.P.H.; Jones, H.P.; Kameda, K.; Palmborg, C.; Schmidt, S.; Ellis, J.C.; Orrock, J.L.; Wait, D.A.; Wardle, D.A.; Yang, L.; Young, H.; Croll, D.A.; Vidal, E. 2011. Impacts of seabirds on plant and soil properties. Pp 135-176 in Mulder, P.H.; Anderson, W.B.; Towns, D.R.; Bellingham, P.J. (eds) *Seabird islands: ecology, invasion and restoration*. New York, Oxford University Press.

Mulder, C.P.H.; Keall, S.N. 2001. Burrowing seabirds and reptiles: impacts on seeds, seedlings and soils in an island forest in New Zealand. *Oecologia 127*: 350-360.

Priddel, D.; Carlile, N.; Wheeler, R. 2006. Establishment of a new breeding colony of Gould's petrel (*Pterodroma leucoptera leucoptera*) through the creation of artificial nesting habitat and the translocation of nestlings. *Biological Conservation 128*: 553-563.

Rabouam, C.; Thibault, J.-C.; Bretagnolle, V. 1998. Natal philopatry and close inbreeding in Cory's shearwater (*Calonectris diomedea*). *Auk 115*: 483-486.

Richdale, L.E. 1944. The titi wainui or fairy prion *Pachyptila turtur* (Kuhl). *Transactions of the Royal Society of New Zealand 74*: 32-48.

Richdale, L.E. 1965. Breeding behaviour of the narrow-billed prion and broad-billed prion on Whero Island, New Zealand. *Transactions of the Zoological Society of London 31*: 87-155.

Serventy, D.L. 1967. Aspects of the population ecology of the short-tailed shearwater. *Proceedings of the XIV International Ornithological Congress*: 165-190.

Serventy, D.L.; Curry, P.J. 1984. Observations on colony size, breeding success, recruitment and inter-colony dispersal in a Tasmanian colony of short-tailed shearwaters *Puffinus tenuirostris* over a 30-year period. *Emu 84*: 71-79.

Serventy, D.L.; Gunn, B.M.; Skira, I.J.; Wooller, R.D. 1989. Fledgling translocation and philopatry in a seabird. *Oecologia 81*: 428-429.

Smith, J.L.; Mulder, C.P.H.; Ellis, J.C. 2011. Seabirds as ecosystem engineers: nutrient inputs and physical disturbance. Pp 27-55 *in* Mulder, P.H.; Anderson, W.B.; Towns, D.R.; Bellingham, P.J. (eds) *Seabird islands: ecology, invasion and restoration*. New York, Oxford University Press.

Smith, V.R. 1976. The effect of burrowing species of Procellariidae on the nutrient status of inland tussock grasslands on Marion Island. *Journal of South African Botany 42*: 265-272.

Taylor, G.A., 2000. *Action plan for seabird conservation in New Zealand*. Part A, Threatened seabirds. Department of Conservation, Wellington, Threatened Species Occasional Publication No. 16.

Walls, G.Y. 1978. The influence of the tuatara on fairy prion breeding on Stephens Island, Cook Strait. *New Zealand Journal of Ecology 1*: 91-98.

Warham, J. 1990. *The petrels: their ecology and breeding systems*. London, Academic Press.

Warham, J. 1996. *The behaviour, population biology and physiology of the petrels*. London, Academic Press.